

Metallic Environmentally Resistant Coating Rapid Innovation Initiative. A. R. Gray¹ and S. Rengifo²,
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Introduction: Lightweight alloys such as aluminum (Al) and titanium (Ti) are often specified for space systems to minimize mass while maintaining structural integrity [1,2]. Such alloys however, have poor tribological response (high friction and wear), especially in extreme space environments, which becomes worse with the additional presence of lunar regolith. This leads to short lifetimes and premature failures that will ultimately limit long term operations on the lunar surface [2]. This project is addressing this technology gap by developing advanced wear- and radiation-resistant coatings for lightweight parts to extend the lifetime and sustainability of both lunar and Martian assets.

Ceramics were considered for their high wear resistance, but were rejected because of their low fracture toughness, which would be especially problematic for structural components. The novel and existing coating technologies and deposition methods are being tested in this project. The coating materials are Boron Nitride-Aluminum (BN-Al), Nickel Titanium (NiTi), Aluminum Oxide (AlO₃), Ti64 with hBN at 2 and 10 vol percent (Ti-2vol%hBN and Ti-10vol%hBN), and the deposition techniques are high pressure cold-spray (CS) and ambient and vacuum plasma-spray (APS and VPS) [3,4,5]. BN-Al, NiTi, Ti-2vol%hBN, and Ti-10vol%hBN were applied with all three deposition techniques, and AlO₃ was applied only using the APS deposition technique. A tungstenite (WS₂) film was applied to the NiTi VPS coating.

The coating and deposition technique configurations are being tested against several key end-use performance parameters. The parameters include the capabilities of the coatings under wear environments such as regolith simulant, thermal cycling from high (120°C) to cryogenic (-173°C), high vacuum (~10⁻⁷ torr), and pre- and post-exposure to ionizing particle radiation. Wear tests include pin on disk, three-body abrasion, and surface erosion by high velocity regolith impacts.

The initial down selection is being performed using on virgin and environmental exposure samples using pin on disk and three body abrasion wear tests. From preliminary assessment of this testing, a few configurations were eliminated. Ti-10vol%hBN could not be applied using CS application and NiTi could not be applied using APS or CS application so these configurations did not get

tested. Early pin on disk wear tests showed poor wear performance of BN-Al so this coating was eliminated early in the testing process. AlO₃ on Al substrate did not survive thermal cycling, but wear testing is continuing for AlO₃ on Ti substrate. A more detailed analysis is being conducted to further reduce the number of configuration for phase II and III.

Phase II testing will include conventionally and additively manufactured substrates with surface erosion testing. In phase III, the coatings will be applied to three mechanism types: channel and slot, ball and socket, and a hinge joint. Each will demonstrate a different type of wear incidence. The mechanisms and their base materials are of direct interest to the end users and infusion points: the Human Landing System (HLS) and the Lunar Surface Innovation Initiative (sustained lunar surface operations). The technology development project is based out of Marshall Space Flight Center, has partnered with Florida International University (Miami, FL) and Plasma Processes (Huntsville, AL), and is supported by a group of NASA mentors from different centers.

References:

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